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HYDRODYNAMIC PRESSURE MEASUREMENT ON THE SONAR DOME OF A CGN-38 CLASS MODEL

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Bethesda, Maryland 20084

HYDRODYNAMIC PRESSURE MEASUREMENT ON THE SONAR DOME OF A CGN-38 CLASS MODEL

by

Lewis E. Motter

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SHIP PERFORMANCE DEPARTMENT

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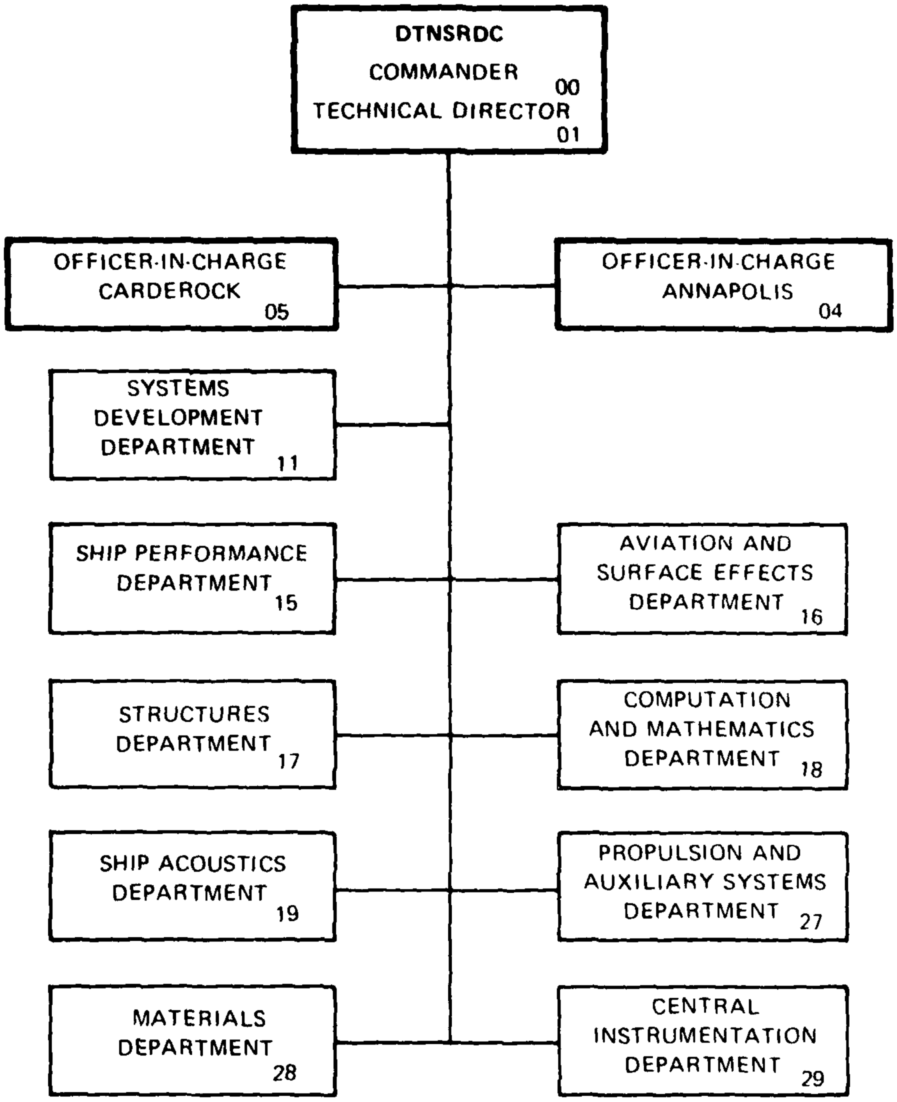

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The hydrodynamic pressure distribution has been measured on the SQS-26 sonar dome of a CGN-38 Class ship model. Experiments were conducted primarily in head regular wave conditions; however, some data was collected in irregular head waves and in regular and irregular waves at 45 degrees off the port bow. Regular wave responses are presented in the form of response amplitude operators and the irregular wave results are presented as significant values of response.

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ABSTRACT

The hydrodynamic pressure distribution has been measured on the SQS-26 sonar dome of a CGN-38 Class ship model. Experiments were conducted primarily in head regular wave conditions; however, some data was collected in irregular head waves and in regular and irregular waves at 45 degrees off the port bow. Regular wave responses are presented in the form of response amplitude operators and the irregular wave results are presented as significant values of response.

ADMINISTRATIVE INFORMATION

This work was funded by the Naval Sea Systems Command under Work Request 02940, dated 11 November 1980. The work is identified at the David W. Taylor Naval Ship Research and Development Center under Work Unit Number 1730-105.

INTRODUCTION

The hydrodynamic pressure acting on a ship is the result of several components including effects from the incident waves, the diffracted waves, and the ship motion in six degrees of freedom. As part of an effort to better understand these effects and to improve hydrodynamic pressure prediction capabilities, model experiments were conducted with a model of the nuclear powered cruiser (CGN-38). The steady and the oscillatory hydrodynamic pressure on the sonar dome was measured and is presented in this report for future use in verifying computer predictions.

DESCRIPTION OF PROTOTYPE AND MODEL

The experiments were conducted using a 23.27 ft (7.09 m) wood model, number 5201, to represent the CGN-38. Particulars of the ship and model are listed in Table 1. The body plan is shown in Figure 1. The model was fully appended with bilge keels, twin propellers and rudders.

The model was instrumented to measure pitch, heave, roll, yaw, sway, and the vertical motion of the bow relative to the water surface. The relative bow motion (RBM) was measured near the nose of the dome at Station 0.5. In addition, the SQS-26 dome was instrumented with six pressure gages at the locations indicated on Figure 2. As shown in Figure 2, four gages were located on the intersection of the dome and the waterline 4 feet below the baseline. The center of the sonar transducer, located on the ship centerline at Station 0.85, was used as a reference to locate the gages. The gages are identified in this report as P1 through P6, as indicated on Figure 2.

RESULTS

All results presented are for the full-scale 560.0 ft (170.7 m) CGN-38 Class ship. During the experiment the model was self-propelled and automatically steered by using a rudder control system with feedback from the yaw and sway motions. It was free to move in all six degrees of freedom. Video tape records provide profile views of the bow and sonar dome during each run.

Regular wave experiments were conducted at 10, 20, and 30 knots in head waves and at 10 and 20 knots in waves 45 degrees off the port bow (referred to as 225-degree waves and bow waves). Irregular wave experiments were conducted in long-crested head waves at 10 and 20 knots in Sea States 5 and low 7 (nominal significant wave heights of 10.0 ft (3.0 m) and 23.0 ft (7.0 m)), respectively, and at 30 knots in Sea State 5. Also, irregular wave experiments were conducted in bow waves at 20 knots in Sea State 7.

At no time during any of the experiment did the sonar dome leave the water. On a few occasions, pressure gage P3 appeared to be at or slightly above the plane of the surrounding water surface. However, the flow around the dome was such that the gage was in contact with the water at all times. No indications of impact loading was observed on any of the pressure gages. Therefore, all measured pressure was sinusoidal and suitable for harmonic analysis.

OSCILLATORY RESPONSE IN REGULAR WAVES

As evidence of the applicability of superposition to this data, the data linearity with respect to wave height was examined for a 20-knot speed in waves with length equal to the ship length. The pitch and pressure measured on gage P4 are shown in Figure 3 as examples of the linear relationship observed between wave height and each motion and pressure measurement.

The transfer functions for pitch, heave and motion of the bow relative to the water surface (RBM) for head waves is shown in Figures 4, 5, and 6, respectively. The pressure at all six dome locations is shown in nondimensional form in Figures 7, 8, and 9 for 10, 20, and 30 knots, respectively. The pressure measurements are arranged on each page for ease of comparison. The results from pressure gages P3, P4 and P5 (located along the stem at the 0, -4 ft (-1.22 m) and -8 ft (-2.44 m) waterlines, respectively) are lined up down the left side of the page. Note that a similar pressure magnitude is measured at each of the three stem locations for the

20- and 30-knot speeds. At the 10-knot speed the most severe pressure was at the P4 location.

The results from pressure gages P2 and P6, located at a 45-degree angle from the centerline to port and to starboard, respectively, are lined up on the top right side of the page. As expected, assuming symmetrical flow around the dome in head waves, a similar pressure magnitude was measured at each of the locations.

The results from pressure gage P1, located at 67 degrees off the centerline to port, is shown in the lower right corner. Potential flow theory has indicated that this location is near the point of minimum static pressure on the dome. As shown in the figures, the oscillatory pressure at the P1 location is only slightly less than that measured at the other gage locations.

The pressures measured at each location are nearly the same for both the 20- and 30-knot speeds. As expected, this agrees with a similar trend between relative bow motion at 20 and 30 knots shown in Figure 6.

Figures 10, 11, 12, 13, and 14 show the pitch, heave, yaw, relative bow motion, and roll, respectively, for regular waves at 45 degrees off the port bow. The yaw motion is highly sensitive to steering. From Figure 12 it can be seen that, with only a few exceptions at 10 knots, the yaw was very consistent.

The pressure at all six dome locations from the experiments in bow waves is shown in Figures 15 and 16 for 10- and 20-knot speeds, respectively.

As was the case for head seas, the pressure measured at location P4 was similar to the pressures at P3 and P5 at 20 knots but slightly higher at the 10-knot speed. As was anticipated, the pressure at the P2 location, facing the incoming waves, was greater than at the P6 location, on the opposite side of the dome, for both the 10- and 20-knot speeds.

OSCILLATORY RESPONSE IN IRREGULAR WAVES

The significant values of the ship motions and dome pressures measured during the irregular wave experiments are shown in Table 2 for all sea states, speeds, and headings considered. The values for the heave at 30 knots in Sea State 5 head waves, the sway at 10 knots in Sea State 7 head waves, and the sway at 20 knots in Sea State 7 bow waves were omitted from the table. Errors occurred in the measurements as a result of an occasional improper position of the model. The model position did not affect other measurements.

Trends observed between the pressures in the regular wave experiments agree with those observed in the irregular wave experiments. The pressure magnitudes measured at locations P3, P4 and P5 are nearly equal (within the accuracy of the experiment) to each other for a given speed. Also the pressure magnitude at any given location is nearly equal for both the 20- and 30-knot speed. As was observed in regular waves, the pressures at the P2 and P6 locations are nearly equal for a given speed in head waves. However, the pressure is slightly less at the P6 location than at the P2 location in bow waves. Finally, the magnitude of the pressure at all locations appears to be directly related to the relative bow motion. As the relative bow motion changes so does the dome pressure.

CONCLUSIONS

Model experiments in regular and irregular waves and in calm water have been conducted with the CGN-38 Class. The motion of the model and the pressure at six locations on the dome were measured and analyzed. Transfer functions from the regular wave experiments and significant values from the irregular wave experiments were presented. From the results the following observations have been made:

1. At no time during the experiment did the sonar dome leave the water or slam.

2. For the 20- and 30-knot speeds, the pressure at the three stem mounted gages was nearly the same in both head and bow wave conditions.

3. The oscillatory pressure appears to be proportional to the relative bow motion.

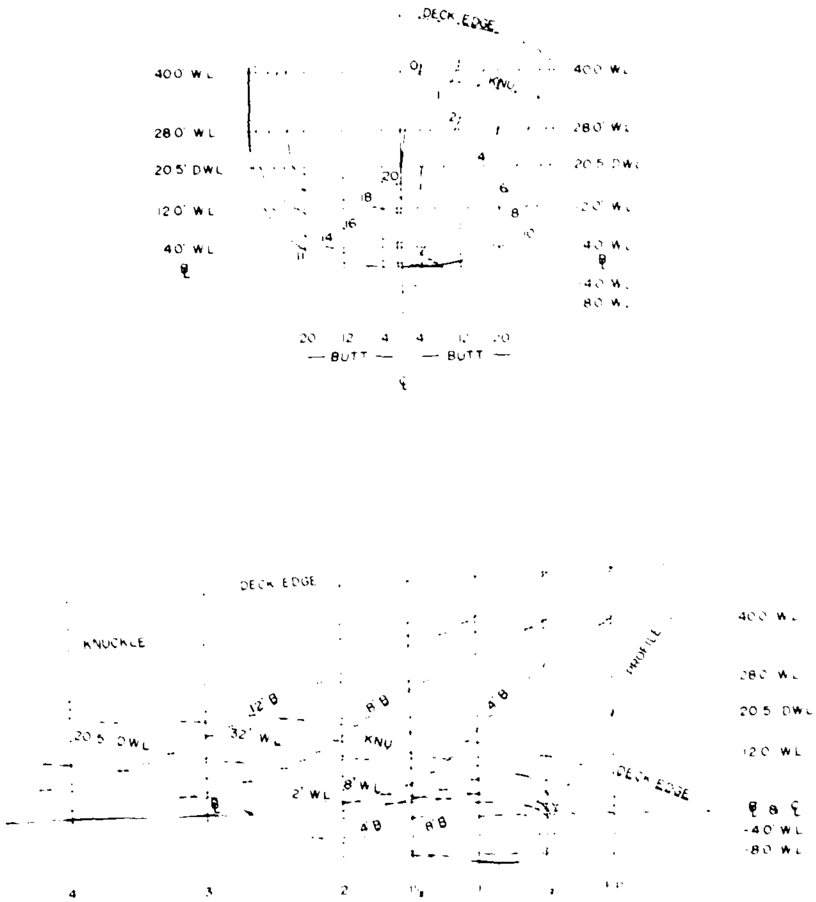


Figure 1 - Body Plan of CGN-38 Class

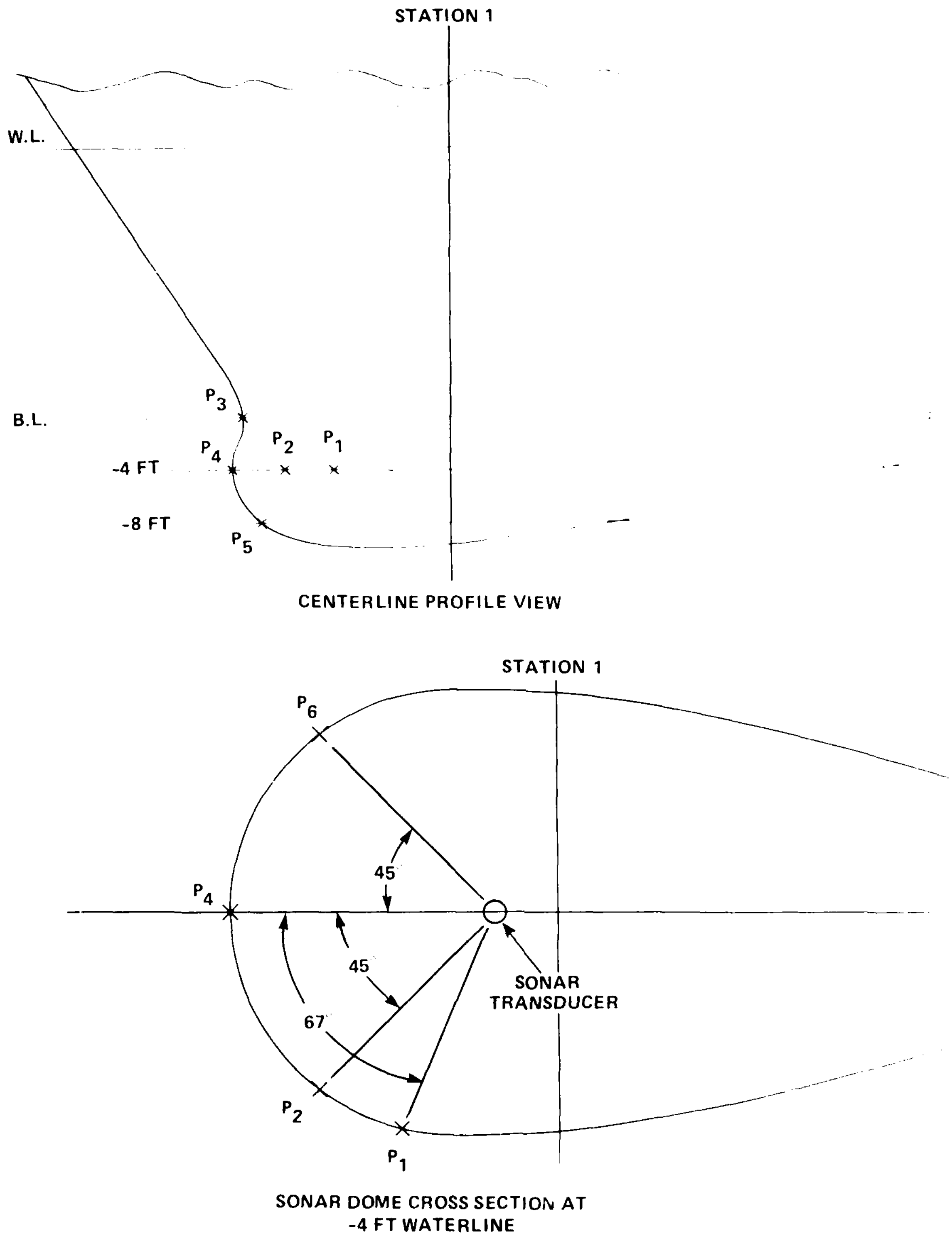


Figure 2 - Location of Pressure Gages on Sonar Dome

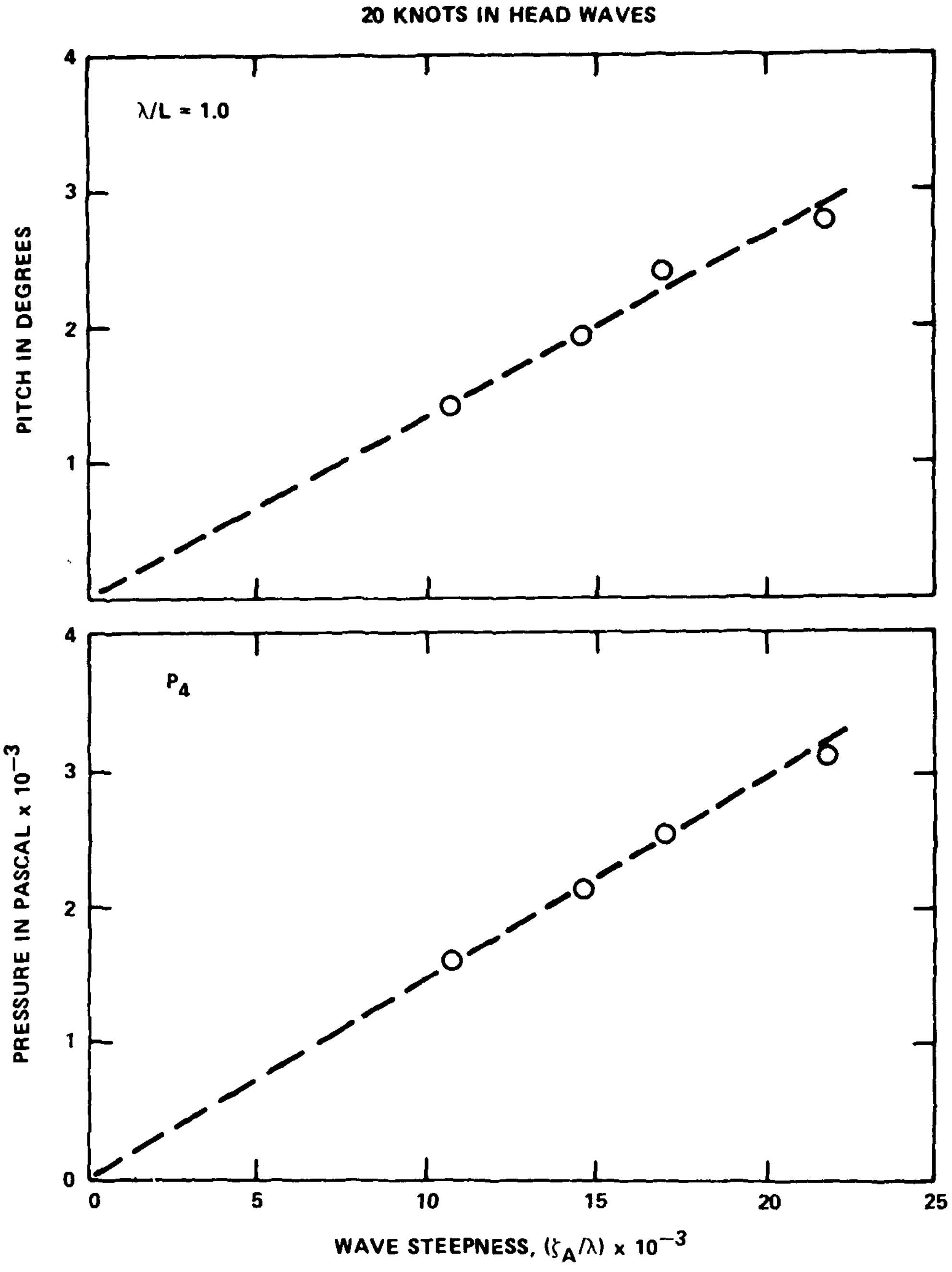


Figure 3 - Pitch Angle and Dome Pressure as a Function of Wave Height

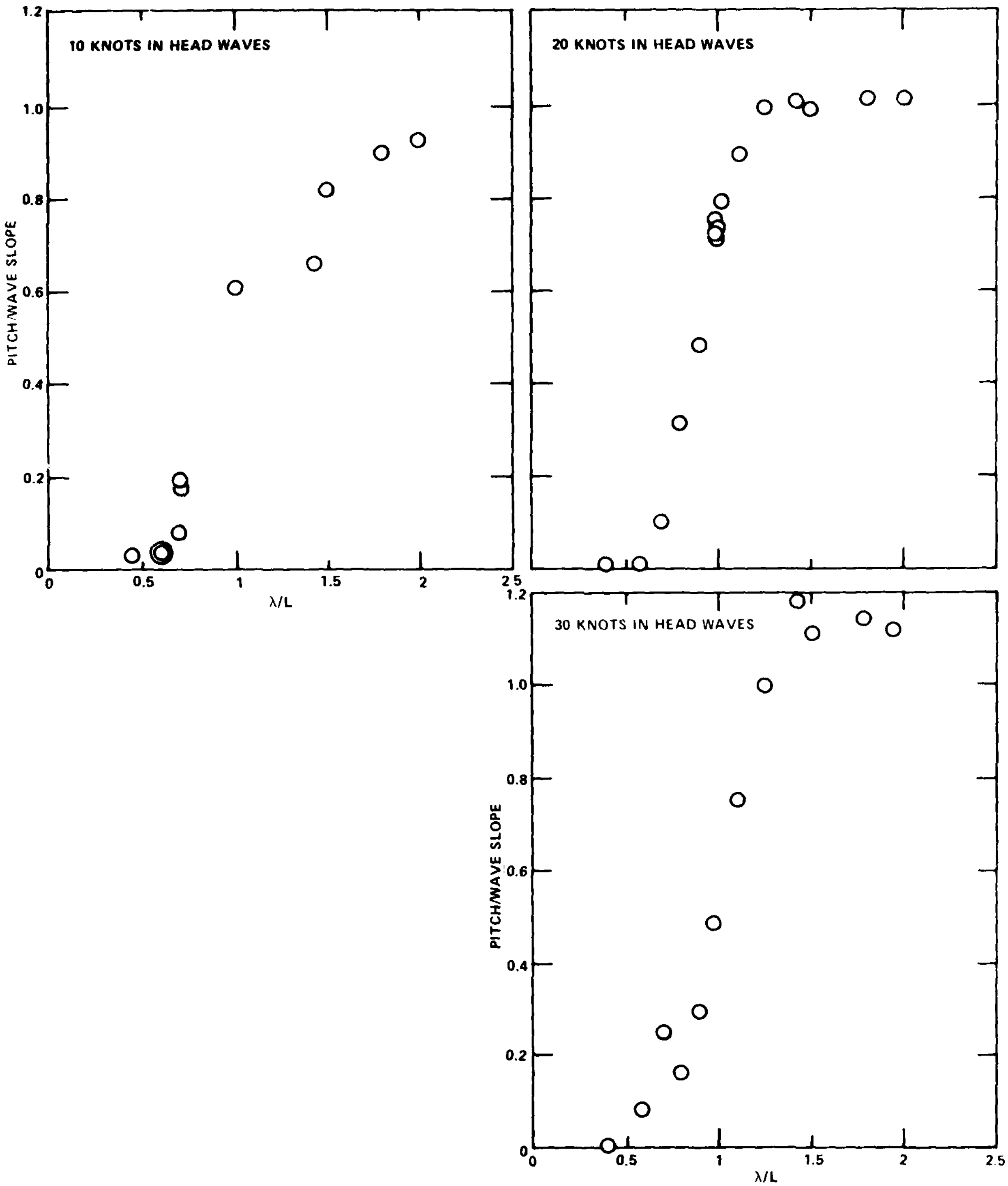


Figure 4 - Pitch Transfer Function for 10, 20 and 30 Knots in Head Waves

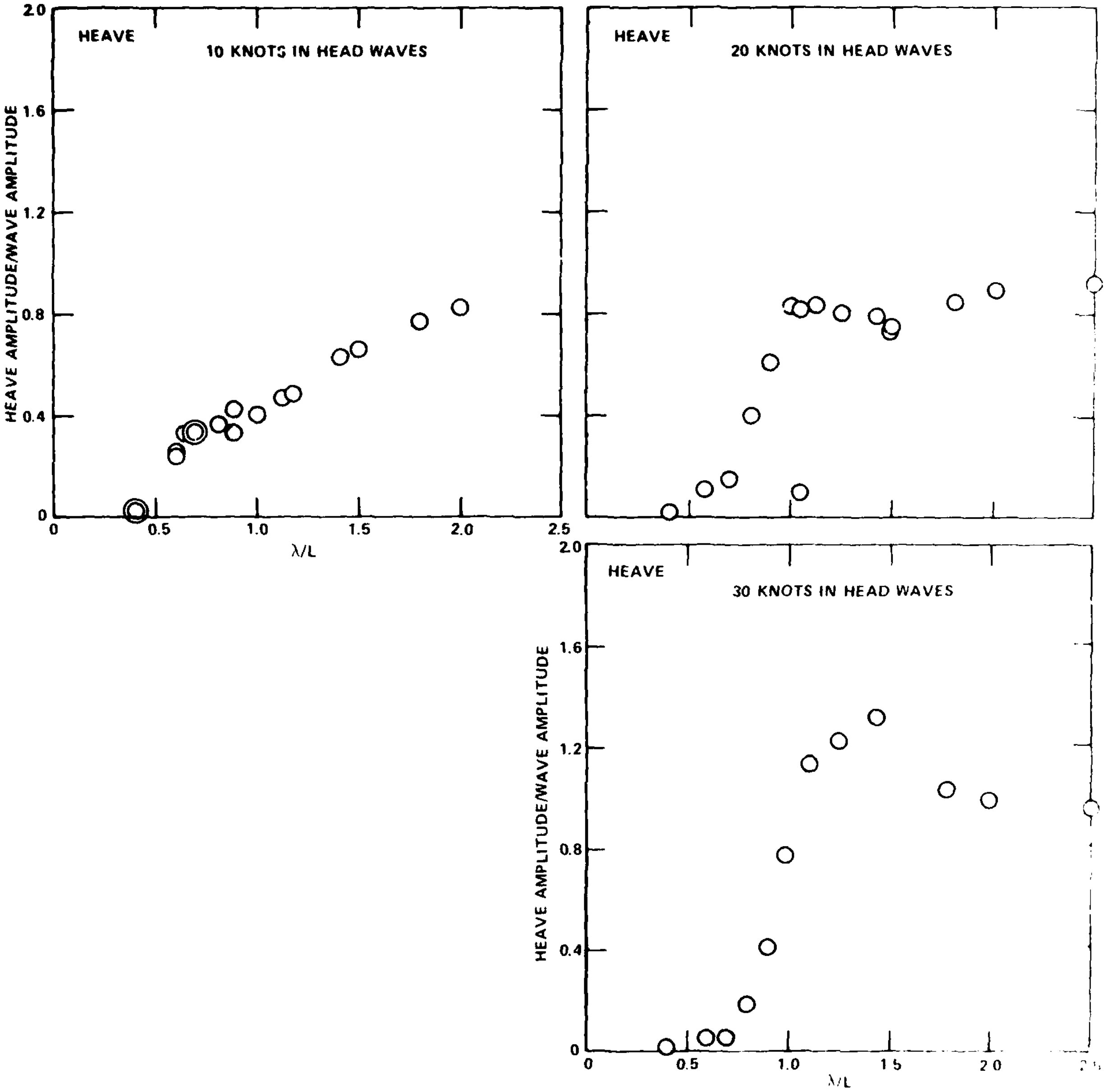


Figure 5 - Heave Transfer Function for 10, 20 and 30 Knots in Head Waves

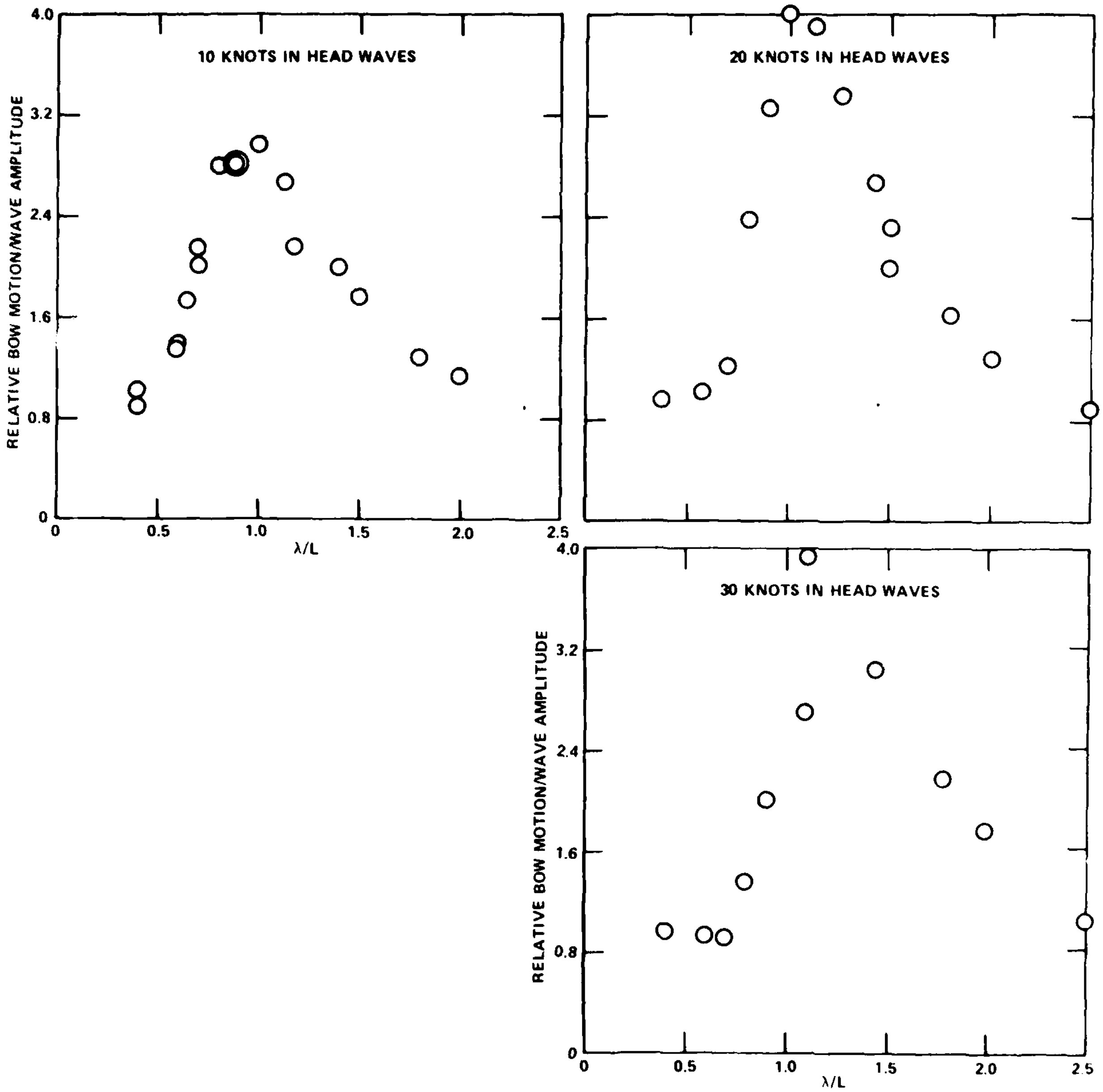


Figure 6 - Relative Bow Motion Transfer Function for 10, 20 and 30 Knots in Head Waves

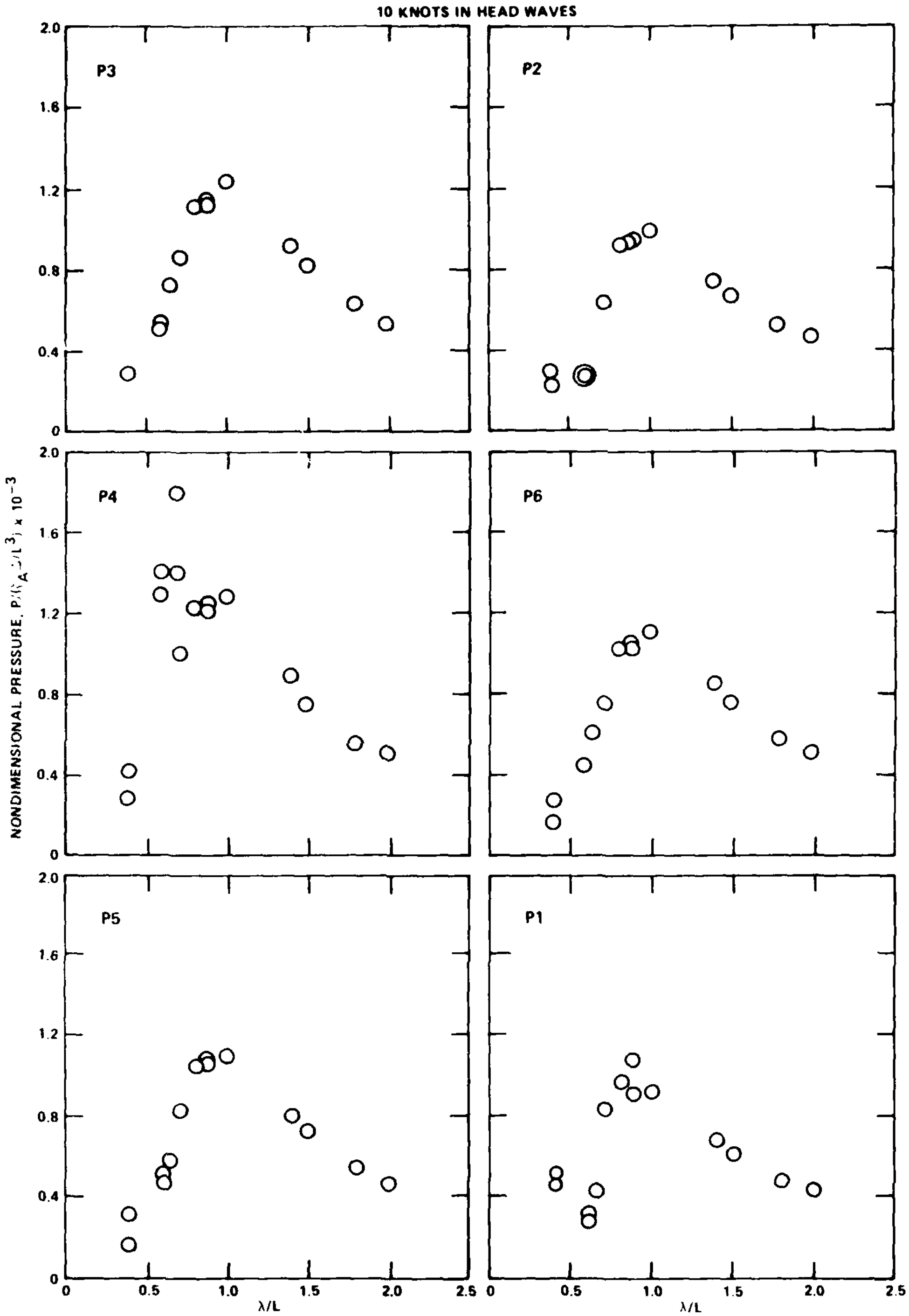


Figure 7 - Sonar Dome Pressure Transfer Functions for 10 Knots in Head Waves

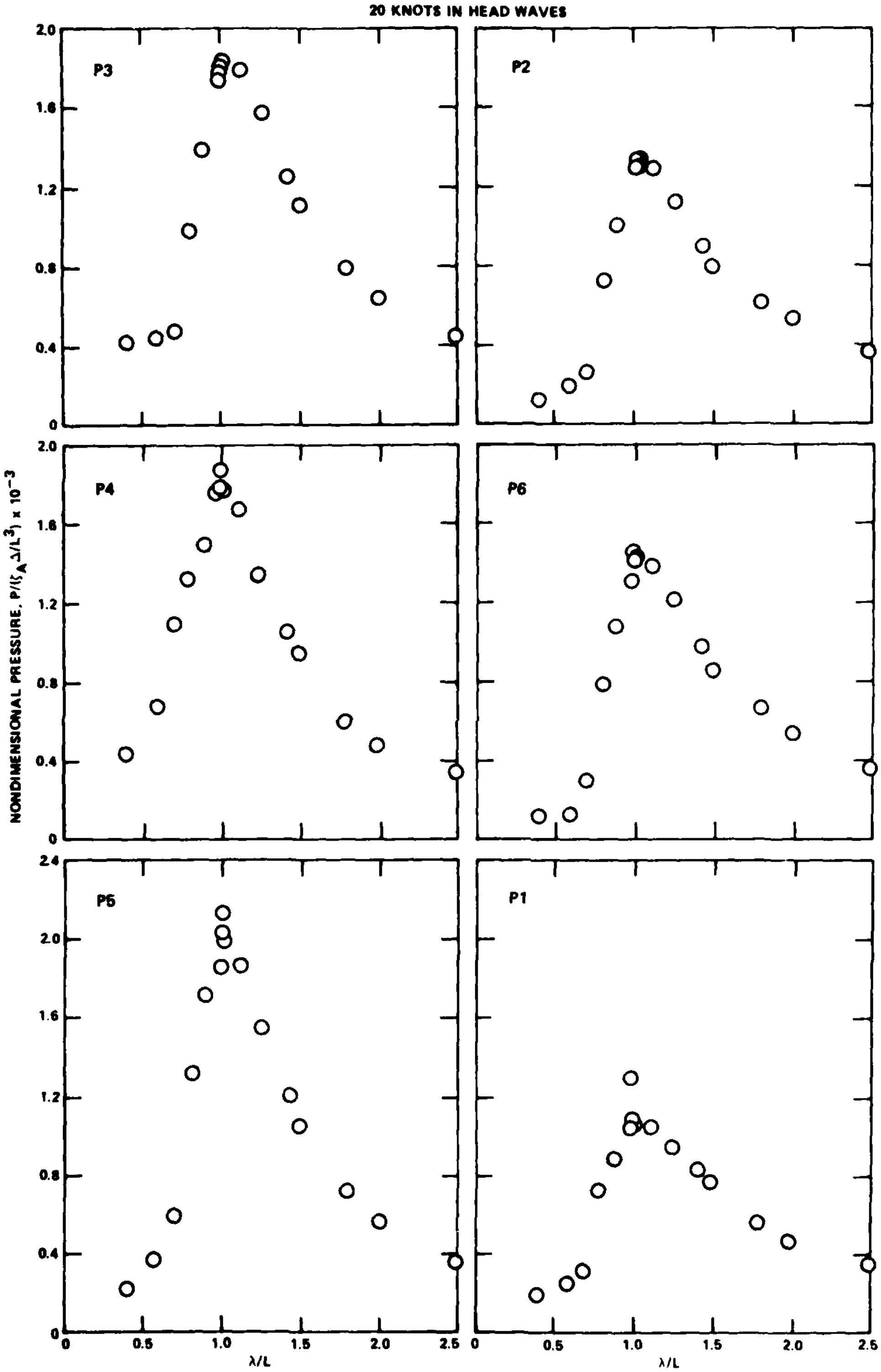


Figure 8 - Sonar Dome Pressure Transfer Functions for 20 Knots in Head Waves

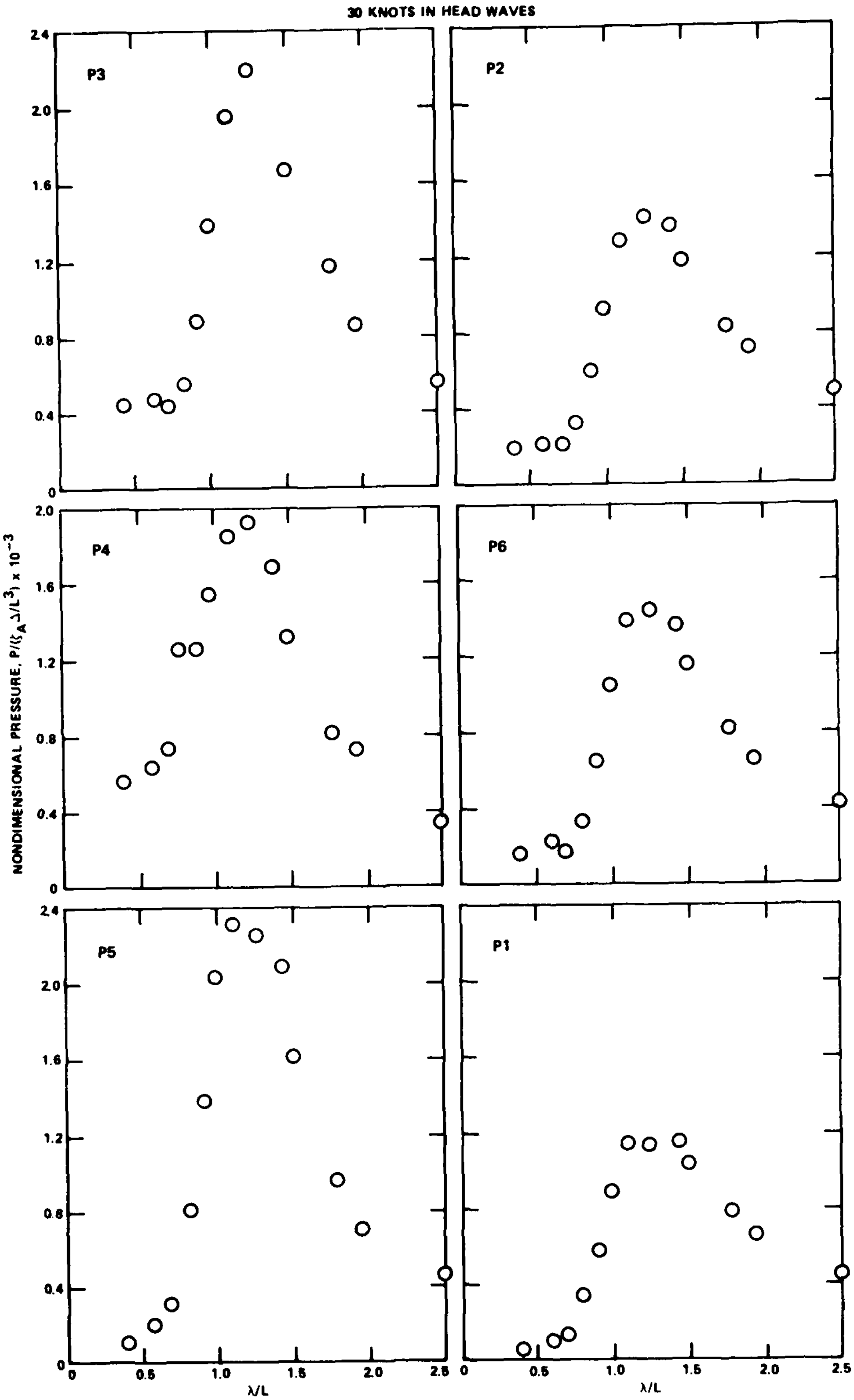
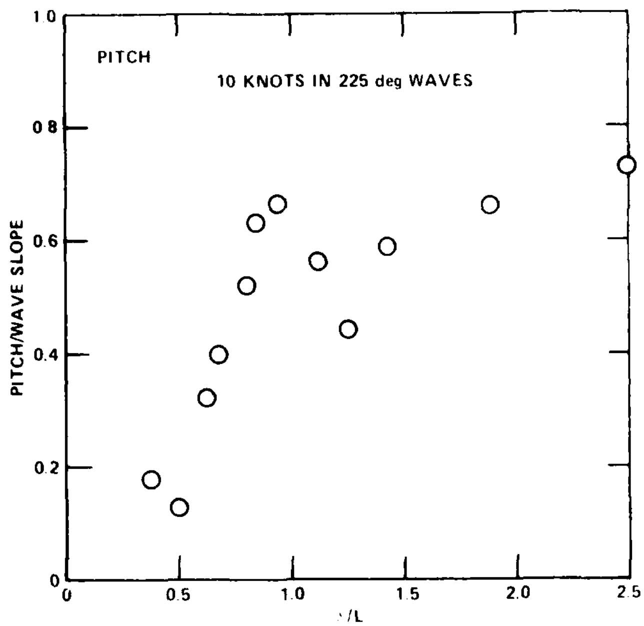


Figure 9 - Sonar Dome Pressure Transfer Functions for 30 Knots in Head Waves



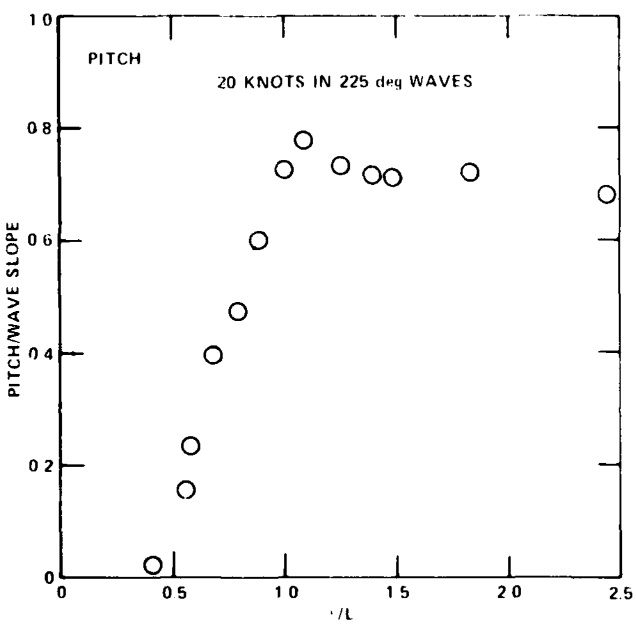


Figure 10 - Pitch Transfer Function for 10 and 20 Knots in Bow Waves

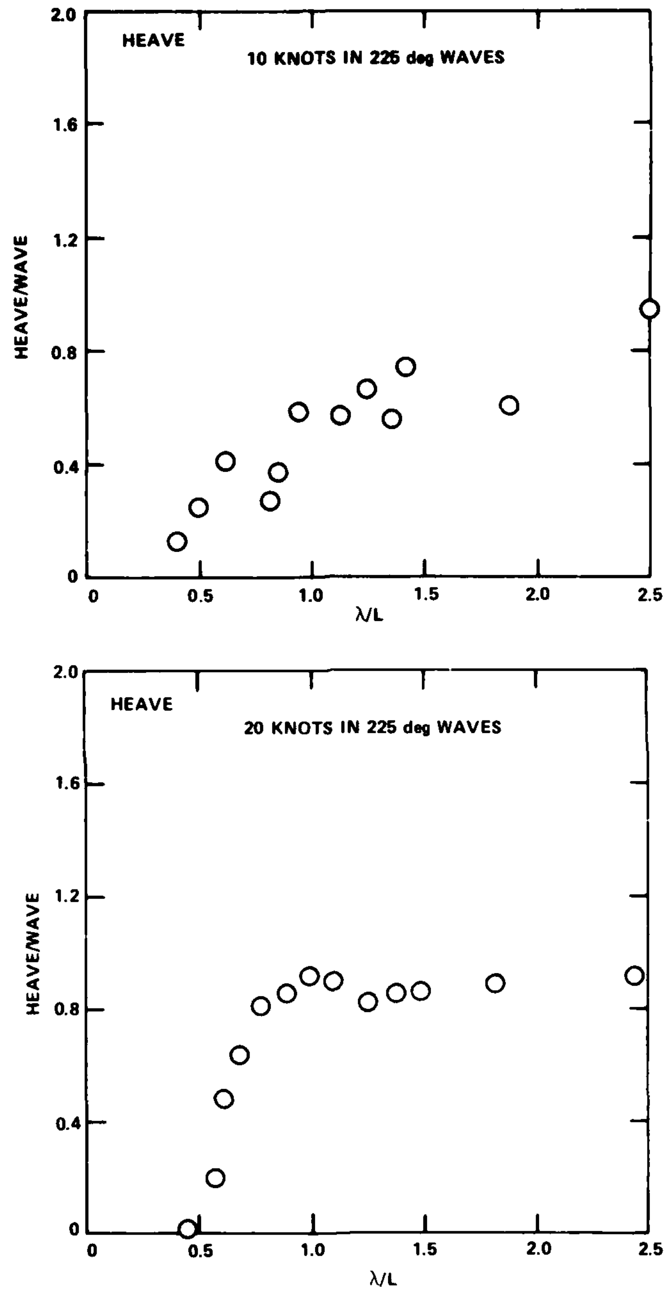
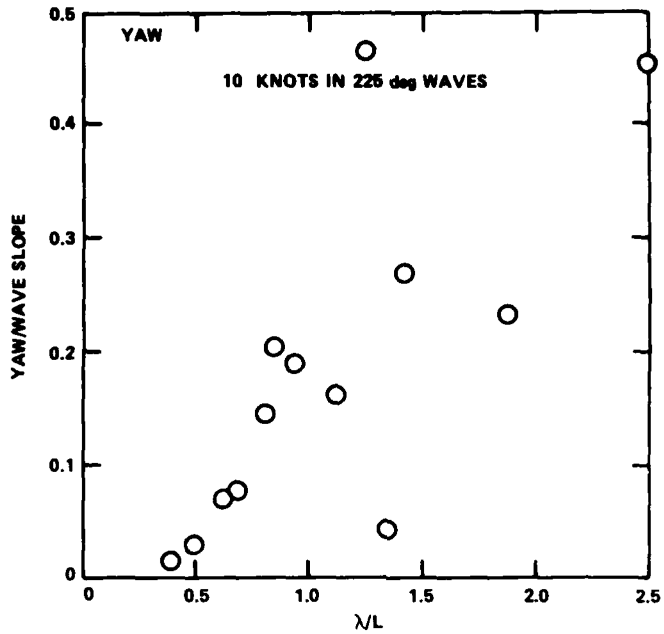


Figure 11 - Heave Transfer Function for 10 and 20 Knots in Bow Waves



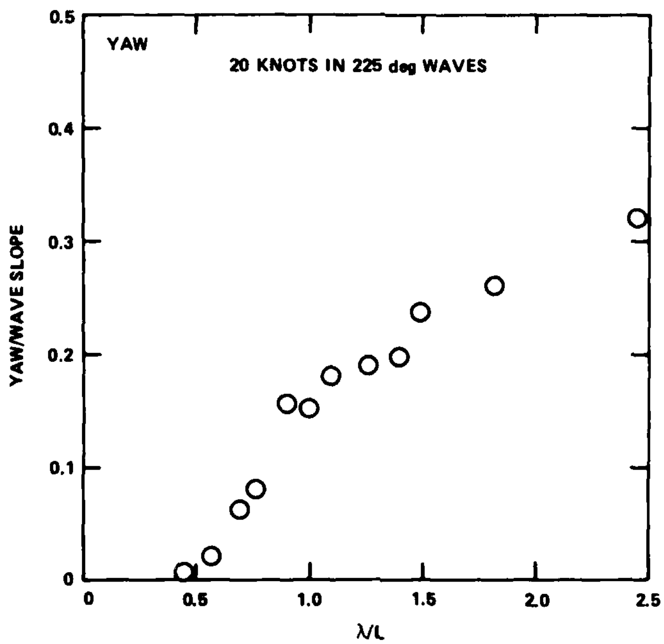


Figure 12 - Yaw Transfer Function for 10 and 20 Knots in Bow Waves

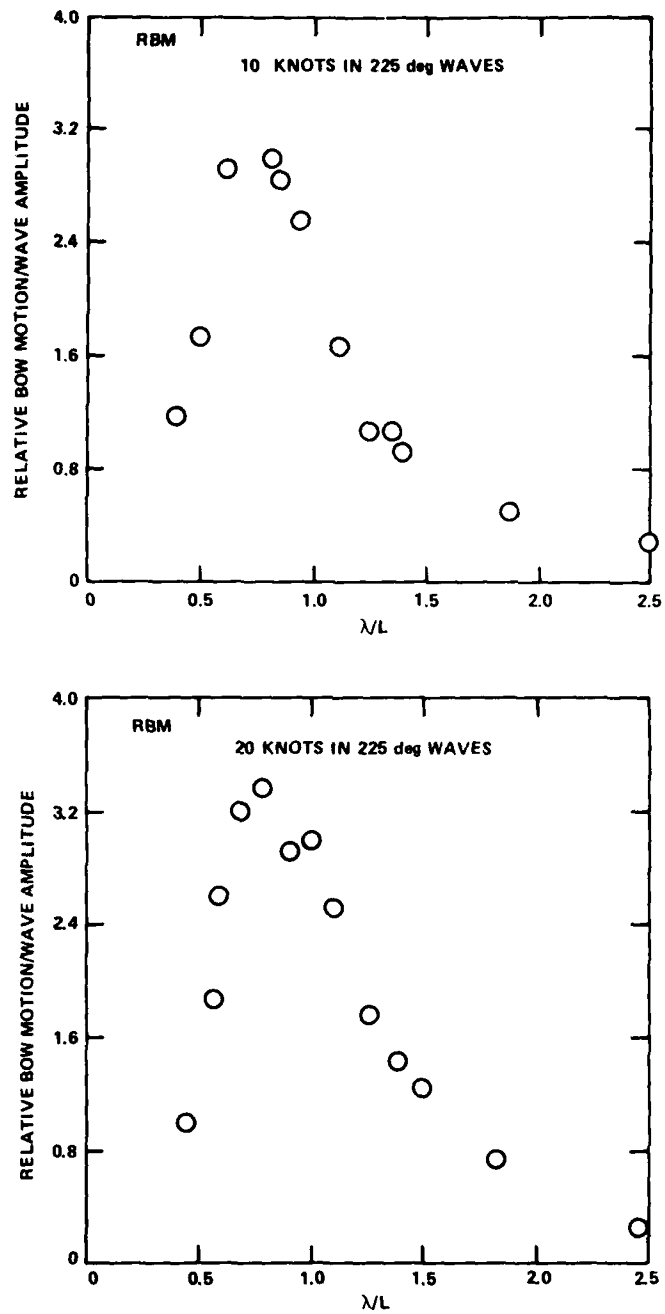


Figure 13 - Relative Bow Motion Transfer Function for 10 and 20 Knots in Bow Waves

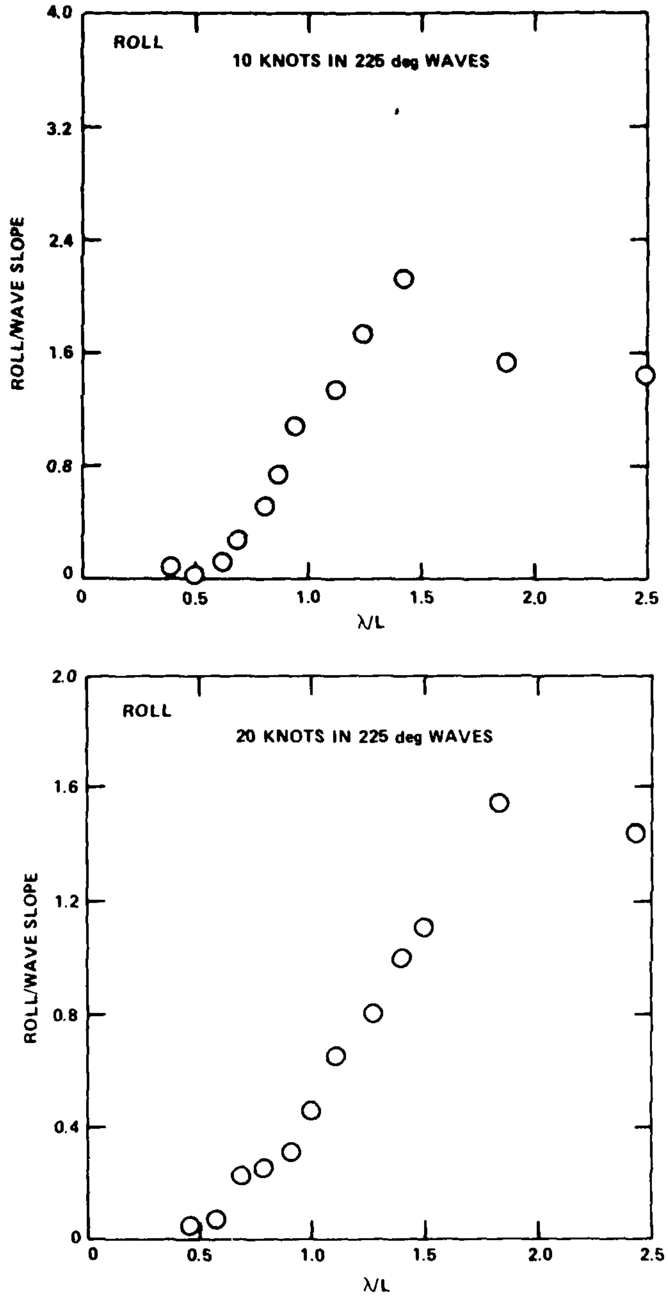


Figure 14 - Roll Transfer Function for 10 and 20 Knots in Bow Waves

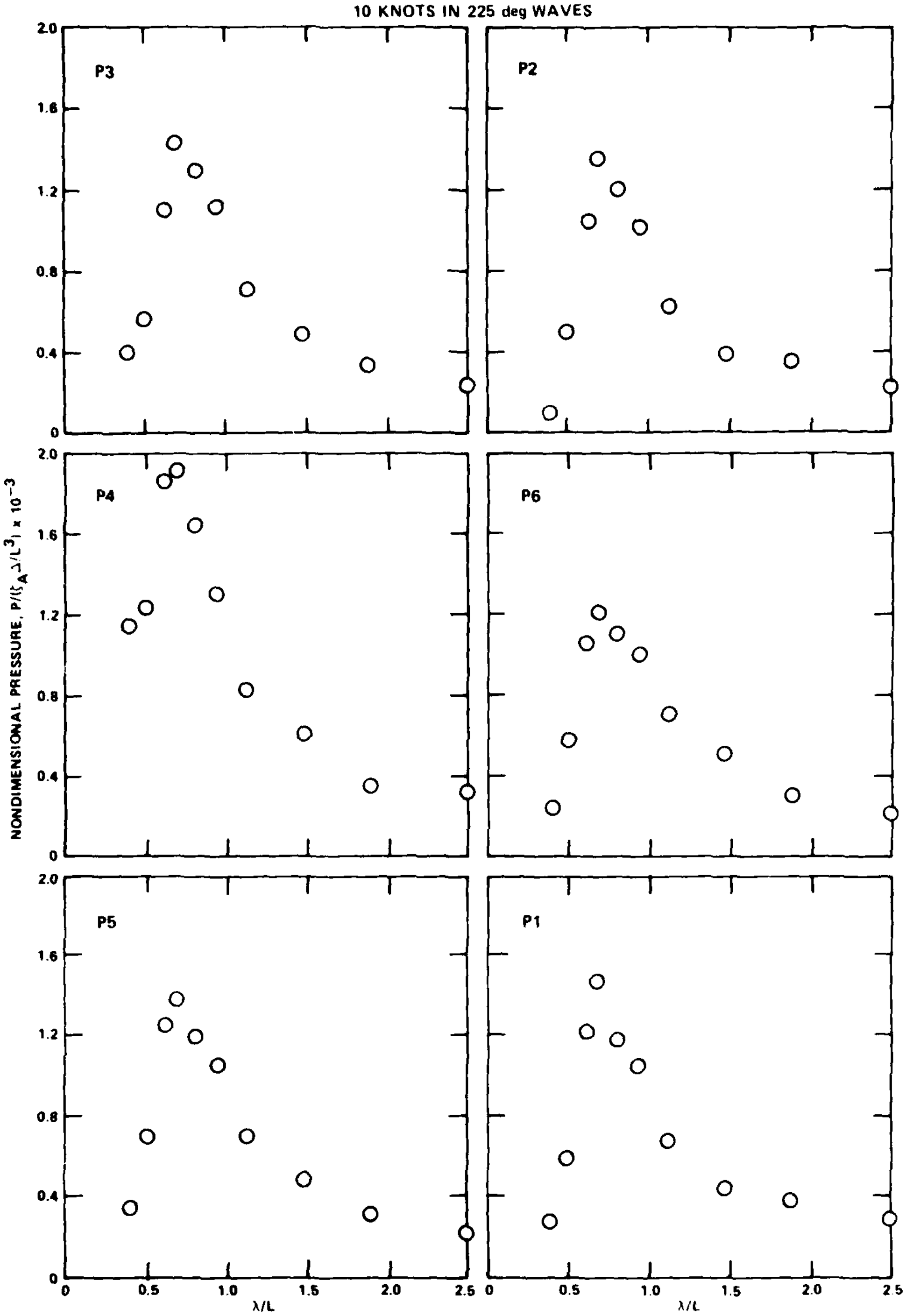


Figure 15 - Sonar Dome Pressure Transfer Functions for 10 Knots in Bow Waves

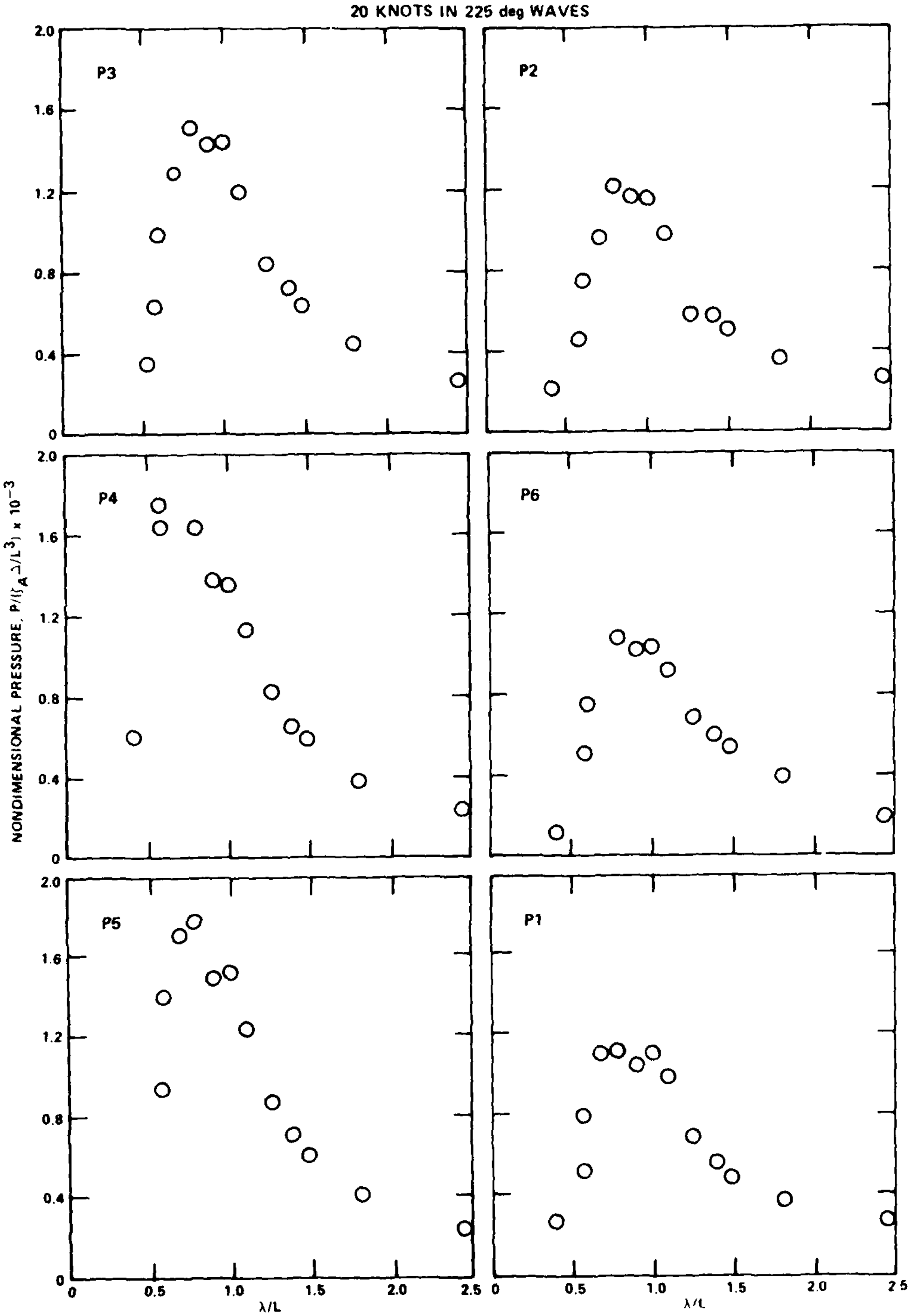


Figure 16 - Sonar Dome Pressure Transfer Functions for 20 Knots in Bow Waves

TABLE 1 - CGN-38 CLASS SHIP PARTICULARS

Parameter	Value	
	Ship	Model 5201
Displacement	12,031 long tons, S.W. (12,224 tonnes)	1885.6 lbs F.W. (855.3 kg)
Length Between Perpendiculars	560.0 ft (170.7 m)	23.27 ft (7.09 m)
Draft	22.7 ft (6.9 m)	0.94 ft (0.29 m)
Beam at Midship	61.90 ft (19.07 m)	2.57 ft (0.79 m)
Longitudinal Center of Gravity, LCG, aft of Midship	8.16 ft (2.49 m)	0.34 ft (0.10 m)
Vertical Center of Gravity, KG (Relative to Waterline)	2.32 ft (0.71 m)	0.10 ft (0.03 m)
Transverse Metacentric Height, GM	4.84 ft (1.48 m)	0.20 ft (0.06 m)
Scale Ratio	24.064	

TABLE 2 - SIGNIFICANT AMPLITUDE RESPONSES FROM IRREGULAR WAVE EXPERIMENTS

	Sea State 5			Sea State 7		
	Head Waves					Bow Waves
Measurement	10 Knots	20 Knots	30 Knots	10 Knots	20 Knots	20 Knots
Wave Height (ft/m)	10.3/3.1	10.9/3.3	10.3/3.1	26.1/8.0	22.6/6.9	23.6/7.2
Pitch (deg)	1.2	1.4	1.5	2.4	2.9	2.7
Roll (deg)	0.6	0.4	0.6	1.1	0.7	3.1
Yaw (deg)	0.7	0.5	0.7	1.0	0.7	2.3
Heave (ft/m)	2.2/0.7	2.8/0.85		4.5/1.4	5.8/1.8	6.0/1.8
Sway (ft/m)	7.7/2.3	5.9/1.8	6.5/2.0		6.8/2.1	
Relative Bow Motion (ft/m)	7.7/2.3	9.8/3.0	11.1/3.4	16.5/5.0	21.3/6.5	17.1/5.2
P1 (psi/Pa x 10^{-3})	3.3/22.8	3.7/25.5	4.1/28.3	7.2/49.6	7.2/49.6	6.4/44.1
P2 (psi/Pa x 10^{-3})	2.8/19.3	3.4/23.4	4.4/30.3	6.0/41.4	7.1/49.0	6.6/45.5
P3 (psi/Pa x 10^{-3})	3.5/24.1	4.6/31.7	5.6/38.6	7.0/48.3	9.6/66.2	8.1/55.8
P4 (psi/Pa x 10^{-3})	5.1/35.2	6.0/41.4	6.5/44.8	8.9/61.4	10.6/73.1	9.4/64.8
P5 (psi/Pa x 10^{-3})	3.3/22.8	4.8/33.1	6.9/47.6	6.4/44.1	9.5/65.5	9.0/62.1
P6 (psi/Pa x 10^{-3})	3.2/22.1	3.7/25.5	4.2/29.0	6.3/43.4	7.5/51.7	6.0/41.4

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